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X-Rays and Metals.

By G. W. C. Kaye, O.B.E., M.A., D.Sc.

X-rays were discovered by Rontgen twenty-four years ago, but it is only within the last few years that the problem of the nature of the rays has been solved. We now know that the X-rays form part of the great family of electro-magnetic rays to which light rays, heat rays, and the waves used in wireless telegraphy belong. The difference between the various types is solely one of wave-length; the distance from crest to crest of a wireless wave may be anything from about one inch up to nine miles, of visible light waves about 1/50,000th in., of X-rays about one hundred millionth of an inch.

Thus X-rays differ only from light rays in the fact that their average wave-length is some ten thousand times shorter. But this very minuteness of wave-length gives them, as Rontgen discovered, the uncanny power of penetrating substances which are opaque to the longer waves of light.

It is in medicine and surgery that the greatest use has so far been made of this singular ability to spy out the interior of an opaque body without cutting it or injuring it in any way. But within the last year or so the X-rays have been turned to commercial account for examining the internal structure of metals and other materials, and the rays have already been employed by, among others, the steel manufacturer, the metallurgist, the aeroplane constructor, the metal welder, the glass manufacturer, the engineer, and the manufacturer of explosives.

How the X-Rays are Generated.

X-rays are generated by passing a powerful electric discharge through an exhausted bulb, near the middle of which is a block of metal called the target, on which the discharge is directed. The discharge is concentrated on a small central area of the target, which area is the source or "focus" whence the X-rays start. Unfortunately only about one thousandth part of the energy developed goes into X-rays, the bulk producing only intense heat at the target. A present-day equipment may develop several horse-power, and a number of ingenious ways of getting rid of this useless heat have been devised. Furthermore, it is essential that the target shall be made of a very refractory metal. Tungsten is usually used nowadays (at one time platinum was always employed), though even a tungsten target (with a melting-point of over 3,000° C.) usually becomes pitted and scarred at the focus.

All that we need consider for our present purpose is that the X-rays radiate in all directions from the focus, travelling in straight lines, just as light rays radiate from a bright source. Unlike light rays, however, they cannot be focussed or deflected by mirrors, lenses, etc.

X-rays are invisible, but they can be perceived in three fashions: (1) by photographic plates; (2) by fluorescent screens; or (3) by their ability to make a gas temporarily conduct electricity. All three methods are used for various purposes, though the photographic is the most familiar.

X-Rays Penetrate all Bodies.

As already mentioned, the X-rays can penetrate all substances, more or less. The shorter the wave-length or the "harder"

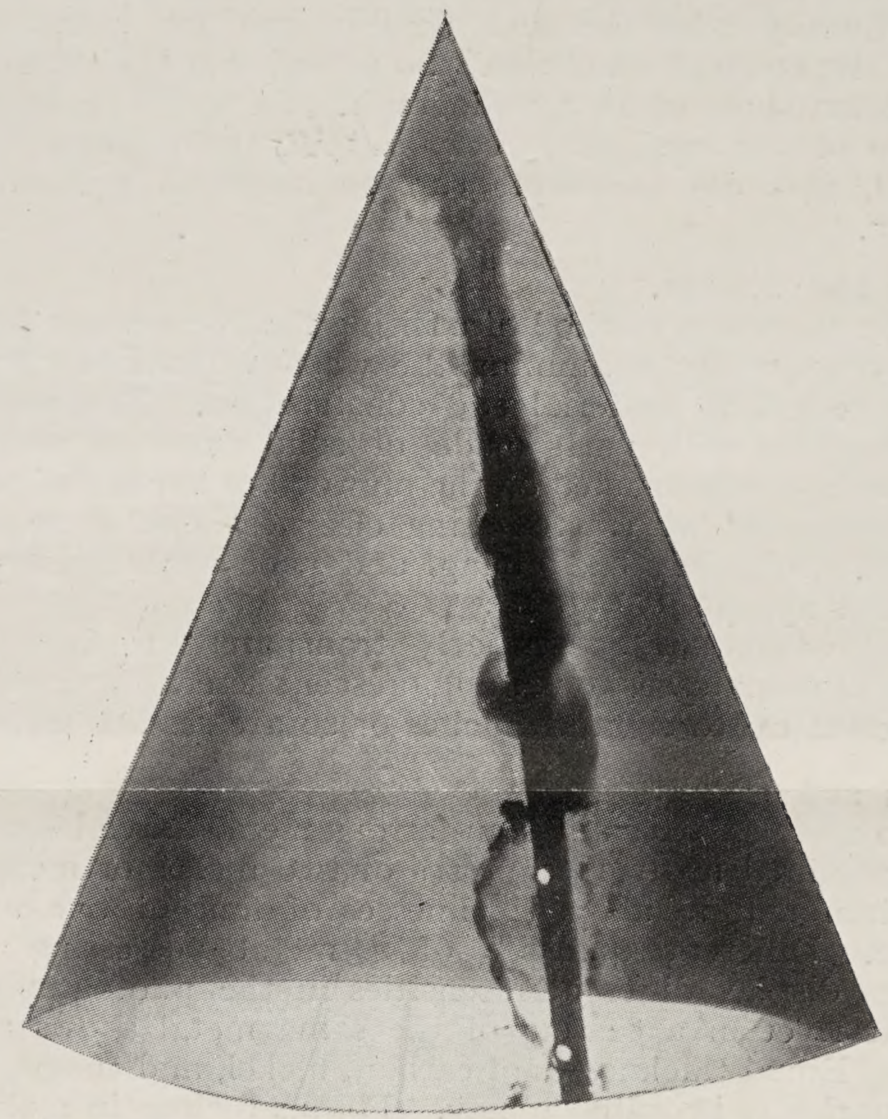

Fig. 1.—Radiograph of conical end of aeroplane petrol tank made of steel sheet, showing seam, solder and rivets.

the X-ray the more easily does it penetrate any substance. There is no distinction between transparent and opaque bodies, as in light; there are only degrees of transparency. The transparency of a body depends both on its thickness and on its

density—or rather, on the weight of the atoms of which it is composed. A lead atom, for instance, absorbs much more than one of iron or aluminium. The transparency is the same whether the atom is free or chemically combined, and it is the same whether the material is hot or cold.

X-Ray Photographs.

In taking X-ray photographs, the body to be photographed is placed between the X-ray bulb and the plate, and, in view of what has just been stated, it will be realised that an X-ray photograph is nothing more than a shadow picture, the degree of "shadow" at each point of the plate being a measure of the extent to which the particular X-ray concerned has been absorbed in its path. In the early days of X-rays, exposures of several minutes were required, now first-class radiographs of any part of the body can be taken with exposures of 1/100th of a second, or less.

The method of X-ray examination is now known to be an extraordinarily sensitive and flexible one for examining the interior structure of materials. So sensitive is it that even tool-marks often show up in a radiograph. As will be gathered, the principle of the method is very simple, the equipment is not involved, and the technique can be mastered without undue difficulty.

X-Rays and Timber.

During the war a method of utilising the X-rays was developed in this country for examining the wooden parts of aeroplanes, both in regard to material and construction. This was not so much the case with parts made of solid wood as with hollow parts, or those constructed on the plywood or laminated principle. The rays reveal with astonishing clearness hidden faults, such as knots, grubholes, bad gluing, and poor workmanship in the internal structure.

As all woods are particularly transparent to X-rays, it is possible in many cases to use a fluorescent screen for examination. Thicknesses up to eighteen inches or so are readily tackled.

X-Rays and Metals.

As to metals, steels and non-ferrous metals have been successfully examined up to thicknesses of two inches or more. With aluminium and its alloys thicknesses of four or five inches are possible. Different qualities of a metal possessing different densities display different intensities in the photograph, *e.g.*, a wrought rivet in a casting of the same metal shows a darker image. Equal thicknesses of carbon, nickel, and tungsten steels differ markedly in transparency. Porous regions in metals show up as light patches. In alloys the uneven distribution of any component yields a "patchy" or streaky radiograph.

Expensive machining may often be saved by initial X-ray examination. Flaws, blowholes, and other defects in castings, forgings and welds (either electric or acetylene) show clearly. In a bad weld the edges of the original plates can be seen, but they entirely disappear if the weld is satisfactory. Blisters and blowholes show up as light spots, their presence affording a guide as to whether the heat has been excessive.

In many cases hidden cracks produced by wrong heat treatment, etc., can be detected, though if they are very fine or tortuous the method is not always successful.

X-ray examination will often diagnose defective soldering or brazing, the improper substitution of one metal for another, concealed rivetting, stopping, or pinning to cover defects or mistakes, and so on.

Many engineering and other firms, more especially abroad, have already installed powerful outfits. Mention should here be made of the care necessary to protect the operator from the harmful effects of the rays. Lead is the only practicable screen which is safe.

The subject of radio-metallography is yet in its infancy, but it promises to be a powerful supplementary weapon for the inspector, at any rate in those cases where the structure is not so complicated and unmanageable as to cast a shadow which cannot be interpreted. With the development of apparatus and technique, in each of which there is much room for improvement, the future will, no doubt, bring remarkable results, as much possibly in heavy engineering as in smaller and refined metal working. The possibilities and limitations of the method will only be unfolded as they suggest themselves from time to time in many varieties of industry. Some of the outcomes will undoubtedly be novel; recent cases which have come to our notice were tests of the

Fig. 2.—Radiograph of defective oxy-acetylene weld between two steel plates, ½ inch thick. (Sunic Research Laboratories).

accuracy of assembly of the wooden spokes in a wheel, the internal structure of a valuable fossil, an elusive fault in a carburetter (taken while in action), the hidden corrosion in a gas cylinder, the structure of golf balls, the centering of the core of an electric cable, the scrutiny of steel turbine plates, and so on. Many other applications will doubtless suggest themselves to our readers.